Optimizing the Preventive Maintenance of the Magnetron

Ruddy I. Risueño Pérez
Master of Engineering Management
Prof. Héctor J. Cruzado, PhD, PE
Civil and Environmental Engineering Department
Polytechnic University of Puerto Rico

Abstract *— Accuray Incorporated is having issues with the random failures of magnetrons in the field. The objectives of this investigation are to prevent downtime due to the failure of the magnetron and to utilize the computer system already available to predict the time of failure of the magnetron so that the field service engineer can replace the part before it fails and avoid the annoyances associated with downtime. These annoyances affect both the company and the customer and according to the collected data it is possible to utilize the already available resources to implement an optimized preventive maintenance program for the magnetron. With the help of the "Research and Development Department", three pieces of software can be generated to analyze data, predict failure and inform the field service engineer that the magnetron replacement is due soon. If this program is implemented, it is projected that it will be beneficial to the entire company because less downtime means less losses of money and time and an improved reputation.*

Key Terms *— downtime, corrective maintenance, computer system integration, maintenance scheduling system.*

INTRODUCTION

Accuray Incorporated is a firm that manufactures radiation therapy systems for the treatment of cancer. The company also has a service side to keep the systems in optimal conditions for operation. It is important to give service and maintenance to the systems in order to keep downtime as low as possible. The Field Service Engineer (FSE) is in charge of doing the "Field Actions", "Corrective Maintenance" and "Preventive Maintenance" services. The FSE is also in charge of representing the firm in front of the customers and deal with the costumer's discomfort and frustration.

It is notorious that a part called a "magnetron" can fail randomly leaving the machine down until a new one is installed. One of Accuray's machines is in Bayamon, Puerto Rico and since it is a remote territory for the United States of America, parts take up to 4 days to ship to the Island. Sometimes the FSE can become frustrated with a down machine just "waiting for parts". A magnetron replacement should take about 4 hours to be performed, but since the part is not on-site, the FSE must wait for FedEx to deliver it. It can be exasperating to both the FSE and the customer to know that a simple repair is being delayed due to a circumstance that can be prevented by just having a part available on-site.

From Accuray's knowledge database, it is known that the average life of a magnetron is about a year, and that they should not be stored for long periods of time, this is why the FSEs are not allowed to have one onsite all the time. But the customer, and its patients are in need of a service, and not having a replacement at hand when the magnetron fails, creates a lot of discomfort for the clinic's staff and the patients. Accuray promises customers an uptime of 98%, and while the customer is down, the company and his clinic are both losing money.

This research's objectives are the following:

- Prevent losses due to downtime.
- Prevent customer discomfort by replacing the magnetron before it fails.

Since Accuray has not conducted any studies to determine the life expectancy of the magnetron it is imperative to collect data to understand this matter.

OVERVIEW

Accuray Incorporated has never conducted a study to determine the life expectancy of the

magnetron and thus, the magnetron is only replaced after failure has occurred. To be able to predict future magnetron failures it is imperative to collect data from each individual site and determine the average life expectancy of the magnetron.

It is known that the computer system has the capacity to monitor the "beam-on" time of each individual machine, but it is also important to investigate if the computer system is capable of coordinating an optimized preventive maintenance schedule. Once all the data has been collected and analyzed, an optimized preventive maintenance program for the magnetron can be deployed. With the deployment of a preventive maintenance program it is expected to have a cost reduction, an improvement on the company's reputation and a competitive advantage can be obtained.

Later on, after the program has been implemented, a customer survey can be developed to verify if the results of implementing such program were successful.

LITERATURE REVIEW

A magnetron is basically a sealed glass bulb that has a cathode that when heated and electrically excited can emit electrons. The main purpose of the magnetron in the radiation therapy devices is to create a standing RF (radio frequency) wave that can accelerate electrons [1]. Without the presence of the radio frequency, the linear accelerator on the machine cannot perform, thus the equipment is considered inoperable. It is important to mention that the cathode, made of nickel oxide, is an integral part of the magnetron that gets worn out with use.

To implement a good preventive maintenance plan, it is important to collect data relevant to the issue that needs to be addressed. Most of the equipment does not benefit from age-related routine maintenance, most of the times it is imperative to study the phenomena that affects the part to be replaced and adjust the maintenance schedule accordingly [2]. In the case of Accuray Incorporated, a routine maintenance plan to replace the magnetron before it fails would be a waste of resources since each clinic has a different patient load and replacing the magnetron due to its age would not be accurate, another measure should be taken into consideration when preparing a preventive maintenance plan other than time alone.

Predictive maintenance uses tools that can monitor variables that affect the performance of certain components. With the use of computer systems, it is possible to collect data and analyze it in order to predict a future failure and take the necessary steps to replace a component or overhaul a machine before it fails [3]. This approach saves the hassle related with downtime and customer discomfort. This is the part of the project that "optimizes" the preventive maintenance program, since the vision is to use a monitoring system to analyze the wear-out time of the magnetron and be able to predict it's time of failure.

It is important to grasp the situation in order to collect the relevant data that will allow to obtain a good path to adjust, control, inspect, evaluate, analyze and improve a process. Day to day there is a lot of data being collected, some of which is not used and might be of great value if the management finds a way to analyze it and optimize its processes. An optimized process is a competitive advantage that can give a leading edge to the firm over its competitors. The creation of graphs and figures are always great tools that will help viewers better understand the information or data that has been gathered [4].

Preventive maintenance includes much more than simply performing routine maintenance on equipment. It also involves maintaining accurate records of every inspection and servicing, as well as knowing the lifespan of each part to understand the replacement frequency. These records can help maintenance technicians anticipate the appropriate time to change parts and can also help diagnose problems when they occur. Preventive maintenance software helps collect and organize this information, so it is readily available to maintenance technicians.

Preventive Maintenance increases equipment lifespan; regular preventive maintenance of assets ensures they remain in optimal condition through

periodic inspection and maintenance. Because the assets undergo minimal breakdowns and perform smoothly, overall lifespan is increased. A well-established PM program will reduce downtime and production disruptions; unplanned maintenance can cost managers a lot of time, labor, and money. Instead, assets that are integrated with a comprehensive preventive maintenance system, such as computerized maintenance management system (CMMS), undergo periodic and planned maintenance. The managers can schedule maintenance as per the asset's requirement and avoid unplanned downtime or disruptions due to asset failure. Depending on the type of business, a PM program can also save energy; assets that are ill-maintained will consume more energy as compared to those that undergo periodic maintenance. This means spending more on the utilities bill. With preventive maintenance merged with assets, you can be sure they perform at their peak levels. This will keep the energy consumption in check, thus also ensuring that you save money of power cost [5].

COLLECTED DATA AND ANALYSIS

Table 1 has data acquired from some of Florida's machines and the two Tomotherapy machines that are in Puerto Rico. This data is representative of the fact that each magnetron gets worn out at a different pace. It can be observed that serial number 110098 was used for 23 hours per week for the last six months, while serial number 110144 only 10. This means that the magnetron of the 110098 should have a shorter life expectancy than that of the 110144. So, replacing the magnetron at a certain time rate instead of by monitoring its use could be a waste of resources. It would be better to monitor the usage and determine the life expectancy in "beam-on" hours.

Figure 1 shows a graphical representation of the fact that every clinic has a different patient load on their machines. Just by looking at the graph in Figure 1, it can be clearly seen that machine 110098 has a lot more patient load than machine 110144. Since the graph is not linear, we can again conclude that replacing the magnetron on a time-based schedule (periodically) could be a waste of resources.

Table 1
Average Weekly Beam-On Hours for the Last Six Months by Serial Number

Machine SN	Average Weekly Beam-On Hours for the Last 6 Months
110098	23
110144	10
110153	21
110181	17
110225	13
110396	14

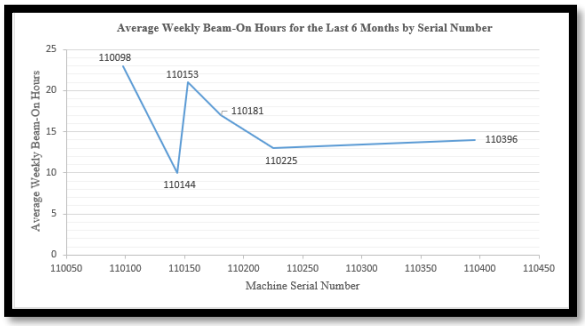


Figure 1
Average Weekly Beam-On Hours for the Last 6 Months by Serial Number

The data utilized to generate both Table 1 and Figure 1 was retrieved from Accuray's database, now it has been confirmed that the data required for the use-based preventive maintenance plan is already being collected.

RESULTS

From the theory of operation of a magnetron it can be understood that magnetron wear depends on use time, not standby time. The already available computer system has access to data that can help predict the failure of the magnetron. Figure 2 explains the different stages required to implement the preventive maintenance plan, which are; data collection, participation of the research and development department and participation of the field service engineer.

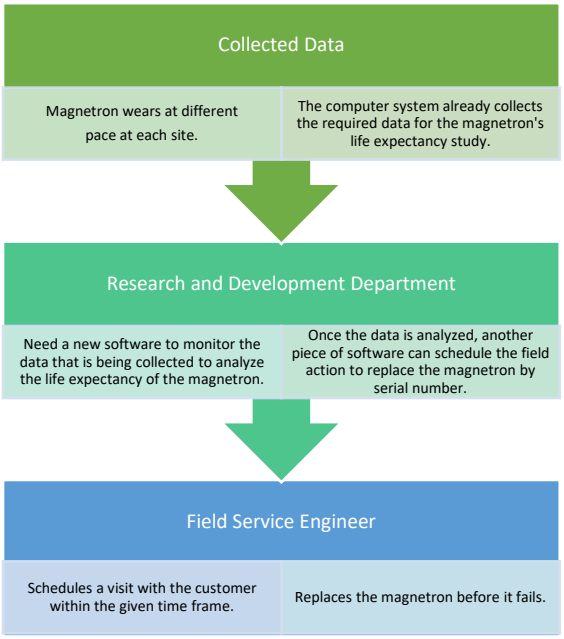


Figure 2
Plan Implementation Overview

Research and development department can implement a computer program to manage the magnetron replacement schedule. Figure 3 shows a flow of the software that is required to create an effective preventive maintenance schedule.

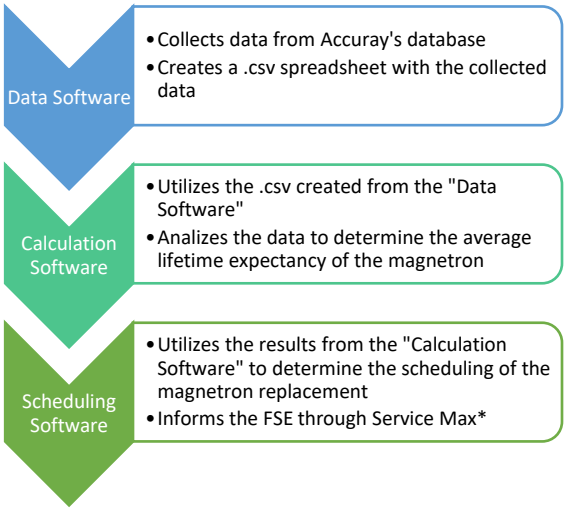
Since it is required to know the "beam-on" time between magnetron replacements, it is important that the "Data Software" program collects the date on which the last two magnetron replacements occurred, between those dates, the "beam-on" time is the variable of interest. If for example the last two magnetron replacements for a specific machine have occurred within exactly one year and the "beam-on" hours that have accumulated during that year are a total of 1000 hours. Then the following equation could be used to determine the replacement time of the current magnetron before failure occurs:

$$Next_{Repl} = (Bon_{Time} x\ 0.95) \quad (1)$$

$$Next_{Repl} = (1000\ x\ 0.95)$$

$$Next_{Repl} = 950\ hours$$

Calculation Software must take each individual case and apply one to determine the next replacement time in "beam-on" hours. It can be seen that the software is informing that the replacement is required when the magnetron reaches 95% of its expected life, this gives the FSE an extra 5% of life that can translate to 2 ½ weeks for scheduling the replacement on a weekend preferably.



*Service Max is Accuray's work order and management system software.

Figure 3
Required Software from Research and Development Department

After the "Calculation Software" has determined the average life expectancy of each individual machine, the "Scheduling Software" can be alerted when the 95% of life expectancy of the magnetron has been reached and this software should communicate with Service Max to add to the schedule the "Magnetron Replacement Field Action" for that particular site.

CONCLUSIONS

At the current time, Accuray Incorporated is utilizing a corrective maintenance approach to deal with magnetron exchanges. Preventive or predictive maintenance are better options for managing machine failures since it eliminates downtime that is an annoyance for both the company and the customer. With a preventive maintenance program, the replacement of the magnetron can be scheduled on a weekend, thus downtime is greatly reduced.

Accuray's computer system is already collecting the data required, but the data is not being used. To make better use of the resources already

available, it is important to integrate the computer system to the calculation and management of the maintenance schedules. A computer system eliminates human error and is a fast and effective way to analyze data, by making the computers work for the company, the company can get a competitive advantage over its rivals.

Manufacturing and service-based companies should always be concerned about customer satisfaction. Current market is very competitive and in order to get superiority it is important to build a satisfied customer base. The main concern with Accuray's customers is the reliability of the equipment since their competitors like Varian and Elekta are older and more solid companies, a good selling point for Accuray's equipment is the reliability. Since the company is promising its customers an uptime of 98% or more, any improvement can make the difference between satisfied or unsatisfied customers. To verify the plan's implementation results and understand if the customer satisfaction expectations were met, a survey could be a desirable tool. A survey amongst customers would let Accuray know if the improvement has been beneficial to their customers and the patients. While a survey amongst the field service engineers would give the company a view of the plan's implementation benefits from the field perspective, remembering that the field service engineers are the ones that deal directly with the customers and schedule the repairs.

REFERENCES

[1] Collin, Robert E. *Foundations for Microwave Engineering.* New York : Wiley-IEEE Press, 2001.

[2] Dixon Campbell, John. *UPTIME. Strategies for Excellence in Maintenace Management.* New York : Productivity Press, 1995.

[3] Stephens, Matthew P. *Productivity and Reliability - Based Maintenance Management.* New Jersey : Pearson Education, Inc., 2004.

[4] Ozeki, Kazuo and Asaka, Tetsuichi. *Handbook of Quality Tools: THE JAPANESE APPROACH.* Cambridge : Productivity Press, Inc., 1990.

[5] Walker, Lindsey. The Importance of Preventive Maintenance. *IMPROVE PRODUCTIVITY. Maintenance Facts.* . Penton Media, Inc. 2017, pp. 10-11.